Magnetization Dynamics with X-Rays

by

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Changing the direction of magnetization is the basic process in key technologies such as magnetic recording or electric transformers. Today's most advanced technologies for magnetization switching are limited to about 1 nanosecond (ns). Scientific experiments on ferromagnets have been carried out on the femtosecond (fs) time scale by use of lasers but the results are controversial. Experiments to determine the motion of the magnetization vector **M** on the fs time scale are therefore one of the most challenging issues in modern magnetism. They are expected to open a new field of research with significant technological impact in the areas of magnetic recording and spin electronics. The pathway of the endpoint of the vector **M** on the sphere of Radius R = M is determined by the precessional torque and the damping torque according to the Landau-Lifshitz (L-L) equation. We discuss the basic processes leading to relaxation of the spin polarization in ferromagnetic metals together with the existing experimental techniques from which the existing knowledge has been obtained. The damping torque is not well understood at the atomic level in nanomagnetic structures. It has been suggested that it depends on the nature of the paramagnetic/ferromagnetic interface, and that even its sign may be varied by injecting spin polarized electrons opening innovative approaches to magnetization reversal and faster as well as smaller bits in magnetic recording. We propose to measure the pathway of **M** at a time resolution of 100 fs by coherent scattering of pulsed polarized x-rays near the 2p-3d resonance of the ferromagnetic transition metals (near 800 eV). The ultrafast magnetic field pulse at an amplitude in the Tesla-range needed to set **M** in motion in realistic materials is readily produced by a well focused relativistic electron bunch passing through the ferromagnetic sample at variable time intervals prior to the arrival of the x-ray pulse. Simulations with the L-L-Gilbert equation on realistic magnetic recording materials demonstrate the wealth of new knowledge expected from this type of experiment.